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THE MISSISSIPPI RIVER FROM CAPE GIRARDEAU TO THE HEAD OF THE PASSES.*

BY

ROBERT MARSHALL BROWN.

Occurrence of High-Water Stages.—The early floods of the year come mostly from the eastern rivers, and usually culminate in March; while the western rivers generally cause a flood in June. An intermediate rise in May is not uncommon when a late rise of the eastern tributaries coincides with an early rise of the western. Great floods occur at intervals. The following table estimates the average conditions (Reports '83, 26):

STATION.	YEARS.	FLOODS.	HEIGHT OF FLOODS EXPECTABLE ONCE IN 10 YEARS.
Cairo...........	1862–1883	4 reached 50.8 ft.; highest, 52.4	51.5
Memphis.......	1858–1883	6 reached 34.0 ft.; highest, 35.2	34.5
Helena	1867–1883	6 reached 45.8 ft.; highest, 47.2	46.5
White River....	1862–1883	5 reached 46.6 ft.; highest, 48.5	47.5
Vicksburg......	1858–1883	4 reached 48.8 ft.; highest, 51.1	49.0
Natchez	1858–1883	5 reached 47.9 ft.; highest, 50.3	48.0
Red River......	1867–1883	3 reached 46.3 ft,; highest, 48.6	47.0
Carrollton......	1859–1883	5 reached 15.9 ft.; highest, 15.9	15.6

Cause of High-Water Stages.—The most potent agent in producing floods in the Mississippi has been excessive rains. The waters of the river come from three main sources—the Missouri, the Ohio, and the Upper Mississippi. These rivers are placed in a table for comparison:

RIVER.	DRAINAGE AREA IN SQ. MILES.	AVERAGE ANNUAL RAINFALL.	% OF RAINFALL DRAINING OFF.	% OF TOTAL DISCHARGE OF MISSISSIPPI SUPPLIED.
Missouri..........	541,000	20.9 in.	15	14
Ohio.............	202,000	41.5 in.	24	31
Upper Mississippi.	171,500	35.2 in.	24	18

The Missouri area has its rainfall in May and June, and is a cause of the late floods of the Mississippi. Although the Missouri has the largest drainage area, yet, because of the scant rainfall and the small percentage of run-off, due to an absorptive soil and drying winds, it is hydrologically the least important. It contributes only 14% to the total discharge of the Mississippi. It, however, contributes 60% of all the solid matter borne by the river. The Ohio valley has its heaviest rains in January, February, and March. Its largest tributaries, the Cumberland and the Tennessee, rise in the mountains, and have a copious rainfall, which adds enormous volumes of water to the Ohio. The Ohio is in the track of the storms which come from the Gulf; and although its basin is less than one-half of that of the Missouri, it furnishes over twice as much water to the Mississippi. Melting snow and frozen ground are factors in this large percentage. The Upper Mississippi has its heaviest rainfall in May and June, and its rises unite generally with those of the Missouri. These three rivers yield 63% of the total discharge of the Mississippi. The remaining 37% of the discharge is divided among the other tributaries. The St. Francis, White, and Arkansas Rivers, draining the Ozark plateau, contribute about as much water as the Missouri. The Yazoo and Red Rivers, the remaining large tributaries, are too near the mouth to be dangerous.

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* Concluded from Bulletin No. 5, 1902.

The ordinary sequence of floods is, first, Ohio, then the Upper Mississippi, followed by the Missouri, with the western streams. All these rivers have never been known to be in extreme flood at once. Such a coincidence would produce a discharge of more than 3,000,000 cubic feet per second—twice as large as has ever been observed. The most dangerous conditions occur in early spring, accompanying the cyclonic storms which cross the country.

While excessive rains are the prominent cause of floods, a number of factors influence their value.

a. Condition of ground, whether frozen or vegetation-covered.

b. Condition of ground as to moisture. A slow rainfall of two inches extending over three days may produce only a very slight rise in a river, while the same amount in two hours may produce a very great one. A rapid rainfall forms a water surface over the ground, which promotes a rapid transfer of a great part of it to the stream. In summer the ground is so dry that in a slow rainfall there is little run-off.

c. Height at which the flood finds the lower trunk.

d. Duration of rise. A sudden rise up river flattens out as it proceeds down stream.

e. Local rainfall in the lower valley.

f. The clearing of forests has been shown (Russell, I. C., '98, 209) by experiments to have no direct effect in increasing river stages. The increase in erosion, however, following the removal of vegetation, may so increase the load of a stream that disastrous floods result.

EFFECTS OF HIGH-WATER STAGES.—The increase in the power of the river during times of flood intensifies the scouring and cutting of the banks and precipitates cut-offs. The great disasters of floods come from the occurrence of crevasses and the discharge of the water over the surrounding country. The territory subject to submergence consists of certain basins along the river—the St. Francis, 6,706 square miles; White River, 956; Yazoo, 6,648; Tensas, 5,370; Atchafalaya, 8,109; and Pontchartrain, 2,001; aggregating 29,790 square miles. These rich bottom lands offer exceptional advantages to the pursuit of agriculture, and only as those already occupied continue to be populated, and others, sparsely settled because of the risk, increase in population as the danger is checked, can the great expense (for levees alone estimated in 1898 at $34,310,795.34, with $18,000,000 needed to complete the system) be justified.

The 1897 flood was considered an exceptional flood; 13,000 square miles of the basin lands were submerged, and the destruction of live stock and crops caused a loss of some $13,000,000. In comparison with the 1882 flood, the waters of the 1897 flood were 22 days less above the danger line. It was remarkable, however, in that it remained a longer time at its highest stage. A comparison of the two floods is interesting.

STAGE OF THE RIVER.	1882.	1897.
River above danger line	81 days.	59 days.
River 2 feet above danger line	68 days.	56 days.
River 4 feet above danger line	63 days.	51 days.
River 6 feet above danger line	47 days.	47 days.
River 8 feet above danger line	15 days.	42 days.
River 10 feet above danger line	9 days.	19 days.

A flood moves as a wave down the stream. T. Russell states ('95, 211) that the wave moves with a velocity dependent on the slope of the river and the mean hydraulic depth, and does not differ a great deal from the velocity of the water. It is probably much slower. The crest of the 1897 wave showed on the hydrographs a progress from Cairo to Carrollton, 270 miles, at an average rate of 1 foot per second, while the average velocity of the river varies from 2 to 5 feet per second.

The difference in height between high and low water at St. Louis is 37 feet; this increases to 51 feet at Cairo because of the Ohio; it then, with slight fluctuations, gradually decreases in amount until at the Head of the Passes the difference between high and low water is but 2.3 feet. The flood loses its power as it goes down stream, and a long river, therefore, cannot have a disastrous flood in its lower courses. The crest of the wave spreads out, and is, therefore, self-destructive. Reference to Figure 9 will show that from the crest A to B the water will have a tendency forward equal to its normal flow under a similar volume, and a normal slope *plus* the impetus due to gravity because of the height of the crest. On the other hand, from C to A is up the back slope of the crest, and a retardation of the waters occurs. In this manner the water is spread over a larger area as it progresses down stream.

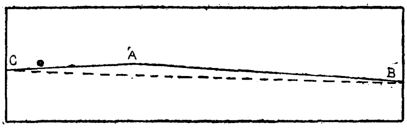

FIG. 9.

PREVENTION OF FLOODS.—*a.* By Reservoirs: The country about the headwaters of the Mississippi is peculiarly adapted to the construction of reservoirs. Many persons have maintained that the excessive floods in the river may be mitigated by the retention of a considerable portion of the waters of the larger tributaries until a time of lesser flow. But, inasmuch as destructive floods are often dependent on favourable local conditions, as, for instance, the floods of a swollen tributary superimposed on a swollen river, unless the reservoir system is widely extended its appreciable effects will be small. Its extension to an efficient means of preventing floods is chimerical. Starling has recorded ('97, 2–4) that, to reduce the floods of the Mississippi 1 foot for 2 months, 13 reservoirs, each 110 feet deep and 7 square miles in area, would be necessary.

b. By Outlets: Another scheme to retard the height of floods is to provide more outlets for drainage. Considerable uncertainty prevails among the engineers as to why the outlet plan cannot be recommended, but they are united in the belief that no relief from flooded conditions can be looked for from them. No single outlet could suffice, and the Lake Borgne outlet, so urgently advised at one time—if the water could be induced to flow into the lake—would soon be shoaled by sediment. It has been shown that disastrous floods do not occur in the lower reaches, so the only effect an outlet would have that might be valuable would be to accelerate the velocity of the river, and thus decrease the time of water above the danger line. Outlets, where they are needed between Cairo and Vicksburg, might be of great utility; however, the relief of the river at the expense of flooding the back swamps and bottoms destroys the purpose of levees. Crevasses occur as natural avenues of relief. The Nita Crevasse of 1897 discharged 30 per cent. of the entire waters of the river, but fifty miles above the break the height of the flood was not visibly affected.

c. By Diversion of Tributaries: No such works are practical except at enormous expense; and even if money was available, the injury to navigation which would surely result would forbid the execution. Furthermore, there is a question concerning the efficiency of the plan. The Po is quoted (Reports, '90, 3,093) as a river on which the opposite plan, addition of tributaries, was tried with good results. In 1600 the Panaro River, almost the equal of the Po, was joined with the latter; and in 1720 the Reno was added to its tributaries. The increased volume of water, and the consequent increased velocity of current, is reported to have caused the Po to deepen and widen its channel, and the liability to overflow was greatly diminished.

d. By Levees: The first levee on the Mississippi was built in 1717, at New Orleans, to protect that city from an overflow. This levee was a mile in length. The mileage of levees to-day is 1,300. The height of the 1717 levee was 4 feet. The average height of the Louisiana levees to-day is 12 to 13 feet, and they were hardly sufficient to hold the 1897 flood. The object of the levees is to confine the water of the river within certain narrow limits, and thus prevent the swamping of the valuable bottom lands on either side of the river. South of Baton Rouge there are 40,000 square miles of made land, of which 36,000 can be reclaimed for cultivation, and be valued at the rate of $30 per acre at $690,000,000. The restraining of the river from spreading over the alluvial plain and banking it within narrow limits must place the surface of the floods at higher and higher levels. While a local 4-foot levee sufficed in a river otherwise free to spread, a much-leveed river breaks over a 12-foot levee. The continual increase of the height of the levees is necessary, not because of greater floods, but because of the closer confinement of the waters. Figures of the heights of levees often show a great increase over the former ones, but in many cases the increase is due to the position on the flood-plain. The caving away of the high alluvial banks has forced the building of levees on the ground of the back slope of the flood-plain. Where a levee 5 feet high met the demands in 1874, now a 17-foot levee is needed; the top of the levee, however, is not much higher than before, while the bottom is 10 feet lower.

There has been assigned for the continual increase in levee height another cause—*i.e.*, the rise of the river bed. Investigations on the Po, the Rhine, and the Mississippi show that the bed is scoured out if anything happens during the increasing height. The extreme low-water surface of the Po increased 1-50 of a foot per year, and the measurements are doubted, while the low-water surface of the Rhine and the Mississippi appears to have fallen. In any circumstance little change is apparent. Another objection to levees is that the prolongation of the delta by deposition of sediment will cause an ultimate rise of bed and a future necessary increase in the height of levees. This objection has been answered by calculations which show that in one hundred years the flood height at New Orleans will rise an inch from this cause.

The location of levees is a serious problem. In the eight years subsequent to 1866, 107.5 miles out of 800 miles of levee caved in, in the State of Mississippi. The immediate banks are not, in general, a safe foundation, as undercutting is possible. The levees must always present to the flood a smooth front, sharp salients being avoided. Where caving is excessive, a double system of embankments is recommended. The causes of the breaks in levees include:

a. Insufficiency in height. The criterion for height has been the highest known water-mark. The increased construction, as has been shown, demands higher and higher levees. Crevasses have been common occurrences; and as the efficiency of levees increases and crevasses become less the rule, the standard height will be attained.

b. The stirring of a full river into action by winds. The March floods, accompanied by high and persistent winds, are much dreaded.

c. Unsoundness or faulty construction. Here may be placed insecure or treacherous foundations and injudicious cross-sections.

d. Maliciousness. There have been recorded—strange to say—breaks that result from a desire for revenge, because of a private hostility against a wealthy planter. Again, landowners, under the threatening break and destruction of their own property, have relieved the strain by opening the levees on the opposite bank. The swampers, who in the dry season cut timber for the market, and who have depended on the overflow to raft their logs, have claimed that the levees were injurious to their business. Breaks have been attributed to these men.

e. Burrowing of animals.

The increasing efficiency of levees is attested by the following table:

In 1882, 284 crevasses occurred, aggregating 59.09 miles.
In 1883, 224 crevasses occurred, aggregating 34.1 miles.
In 1884, 204 crevasses occurred, aggregating 10.64 miles.
In 1890, 23 crevasses occurred, aggregating 4.25 miles.

The flood of 1890, which was one of great height and duration, was experienced with 80% of the bottoms free from flood. The 1895 flood in Louisiana was so efficiently restrained that 85% of the territory (15,000 square miles, with property valued at $180,000,000) was protected against complete inundation, and a loss of only 1-6% of the length of the levees was recorded.

LOW-WATER STAGES.—The following table (Humphreys and Abbot, '61, 122) gives a comparison between the average high-water dimensions and the average low-water dimensions of the river:

LOCALITY.	SECTIONAL AREA.	WIDTH.	MAXIMUM DEPTH.
	HIGH WATER.		
Ohio to Arkansas River......	191,000 square feet.	4,470 feet.	87 feet.
Arkansas to Red River.......	199,000 square feet.	4,080 feet.	96 feet.
Red to Bayou La Fourche....	200,000 square feet.	3,000 feet.	113 feet.
Bayou to Head of Passes.....	199,000 square feet.	2,476 feet.	129 feet.
	LOW WATER.		
Ohio to Arkansas River......	45,000 square feet.	3,400 feet.	49 feet.
Arkansas to Red River.......	54,000 square feet.	3,060 feet.	56 feet.
Red to Bayou La Fourche....	100,000 square feet.	2,750 feet.	78 feet.
Bayou to Head of Passes.....	163,000 square feet.	2,250 feet.	114 feet.

Below the Red River there is the least range between the two stages of the river, and sixty-six sections give as the ratio between the high-water and low-water widths 0.91. Above the Red River the variations between the high and low water widths do not vary so regularly, but one hundred and thirty-eight equidistant measurements on the river, from the Ohio to the Red River, yield a ratio of 0.74. The table, however, does not adequately express low-water conditions. As far as navigability is concerned, that is measured, not by the average low-water dimensions of the river, but by the extreme low-water dimensions. The high-water stage is the ruling condition when the bed is shaped and defined. Great masses of sand are carried by the swollen stream and deposited as bars in the channel. The approach towards low water finds these bars a menace to navigation. Back of the bars the water is ponded, and the river bottom presents a series of pools and shoals. As the fall of the water continues, the ponded water breaks through the bars and forms the low-water channel. The formation of this channel, fitted for navigation, depends upon the rate of decline from a high to a low stage. A slow, gradual decline is beneficial. Anything that will reduce the rapidity of the fall from the higher stages is, therefore, desirable, and in this line reservoirs may find a place. Were it not for the magnitude of the task, reservoirs might be constructed to the advantage of the low-water stage in two ways. By slightly reducing high water—always considering the difficulty of knowing what fall of rain to hold in the reservoir—it would lessen the shoaling of the river, and, during the fall of the water, by judicious feeding, a steadiness of volume could be maintained in the river. Lakes and swamps act continually as reservoirs to lessen floods and also to increase the low-water discharge. The argument that drainage and reclamation of swamps and wet lands affect the river flow can find some justification in the consideration of the low-water discharge—that as the natural reservoirs are removed the low-water discharge will diminish and the low-water channel will not be cut out sufficiently to insure a continuous passage. Against all this the main river finds some protection in the extent of its basin and the number of its tributaries. Poor low-water channels are generally found with excessive low-water widths, and a cure for this has been proposed by the Commission by contracting the low-water width to about 3,000 feet. This contraction must result from works in the bed of the river, and not from levees on top of its banks out of contact with the low-water river.

River Correction.—German engineers have advocated and put in execution the plan of river correction in order to solve the problem of a large meandering stream. The Rhine, from Strassburg to Mainz, has been corrected, and is to-day a stream flowing along curves of a large radius, sharp enough to give the river a swinging habit, but not so sharp that the tendency to scour the banks is unmanageable. It is strange that no strong effort of this nature has been seriously advocated by the Mississippi River Commission. The problem demands careful preparation, and should be approached in accordance with correct hydrotechnic principles. In the testimony before the Senate (The Mississippi River Floods, '98, 296–9, Plate 20) a single witness urged the correction of the Mississippi in preference to all other methods, but the map showing the location of the proposed channel was, on the face of it, so irrational as to make the witness's advocacy of the plan of little worth. The natural shape, conditions, and tendencies of the river should be conserved to the greatest extent consistent with the requirements of commerce. The entire energy of the engineers seems to be centred on the completion of the levee system. It is impossible, with the sharp bends in the river, to prevent caving. It can hardly be expected that the levees will serve their purpose effectively so long as bends similar to the Greenville meanders menace any construction.

NEW BEDFORD, MASS., 1902.

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